CHAPTER 26 (Odd)

1. $Z_i = \dfrac{E_i}{I_i};\ I_i = \dfrac{V_R}{R} = \dfrac{1.05\text{ V} - 1.00\text{ V}}{47\ \Omega} = \dfrac{50\text{ mV}}{47\ \Omega} = 1.064\text{ mA}$

$$Z_i = \frac{E_i}{I_i} = \frac{1.05\text{ V}}{1.064\text{ mA}} = \mathbf{986.84\ \Omega}$$

3. a. $I_{i_1} = \dfrac{E_{i_1}}{Z_{i_1}} = \dfrac{20\text{ mV}}{2\text{ k}\Omega} = \mathbf{10\ \mu A}$

b. $Z_{i_2} = \dfrac{E_{i_2}}{I_{i_2}} = \dfrac{1.8\text{ V}}{0.4\text{ mA}} = \mathbf{4.5\text{ k}\Omega}$

c. $E_{i_3} = I_{i_3}Z_{i_3} = (1.5\text{ mA})(4.6\text{ k}\Omega) = \mathbf{6.9\text{ V}}$

5. $E_{o_{\text{peak}}} = E_{g_{\text{peak}}} - V_{R_{\text{peak}}} = 2\text{ V}\ \angle 0° - 40 \times 10^{-3}\text{ V}\ \angle 0° = 1.96\text{ V}\ \angle 0°$

$$I_{\text{peak}} = \frac{V_{R_{\text{peak}}}}{R_s} = \frac{40\text{ mV}}{0.91\text{ k}\Omega} = 43.96\ \mu\text{A}$$

$$Z_o = \frac{E_o}{I_R} = \frac{1.96\text{ V}\ \angle 0°}{43.96\ \mu\text{A}} = \mathbf{44.59\text{ k}\Omega}$$

7. $Z_o = \dfrac{E_{o_{p\text{-}p}}}{I_{o_{p\text{-}p}}} = \dfrac{E_{g_{p\text{-}p}} - V_{R_{p\text{-}p}}}{I_{o_{p\text{-}p}}} = \dfrac{0.8\text{ V} - 0.4\text{ V}}{40\ \mu\text{A}} = \mathbf{10\text{ k}\Omega}$

$$V_{R_{p\text{-}p}} = 2\ \cancel{\text{div}}[0.2\text{ V}/\cancel{\text{div}}.] = 0.4\text{ V}$$

$$E_{g_{p\text{-}p}} = 4\ \cancel{\text{div}}[0.2\text{ V}/\cancel{\text{div}}.] = 0.8\text{ V}$$

$$I_{o_{p\text{-}p}} = \frac{V_{R_{p\text{-}p}}}{10\text{ k}\Omega} = \frac{0.4\text{ V}}{10\text{ k}\Omega} = 40\ \mu\text{A}$$

9. a. $\mathbf{A}_v = \dfrac{\mathbf{E}_o}{\mathbf{E}_i} = \mathbf{A}_{v_{\text{NL}}}\dfrac{R_L}{R_L + R_o} = (-3200)\dfrac{(5.6\text{ k}\Omega)}{5.6\text{ k}\Omega + 40\text{ k}\Omega} = \mathbf{-392.98}$

b. $\mathbf{A}_{v_T} = \dfrac{\mathbf{E}_o}{\mathbf{E}_g} = \dfrac{\mathbf{E}_o}{\mathbf{E}_i} \cdot \dfrac{\mathbf{E}_i}{\mathbf{E}_g}$

with $\mathbf{E}_i = \dfrac{\mathbf{Z}_i\mathbf{E}_g}{\mathbf{Z}_i + R_g}$ and $\dfrac{\mathbf{E}_i}{\mathbf{E}_g} = \dfrac{\mathbf{Z}_i}{\mathbf{Z}_i + R_g}$

$$\mathbf{A}_{v_T} = \frac{\mathbf{E}_o}{\mathbf{E}_i} \cdot \frac{\mathbf{Z}_i}{\mathbf{Z}_i + R_g} = (-392.98)\frac{(2.2\text{ k}\Omega)}{2.2\text{ k}\Omega + 0.5\text{ k}\Omega} = \mathbf{-320.21}$$

11. a. $$\mathbf{A}_v = \frac{\mathbf{E}_o}{\mathbf{E}_i} = \mathbf{A}_{v_{NL}} \frac{R_L}{R_L + R_o}$$

$$-160 = \mathbf{A}_{v_{NL}} \frac{2\text{ k}\Omega}{2\text{ k}\Omega + 28\text{ k}\Omega} = \mathbf{A}_{v_{NL}}(0.0667)$$

$$\mathbf{A}_{v_{NL}} = \mathbf{-2398.8}$$

b. $$\mathbf{E}_o = -\mathbf{I}_o R_L = -(4\text{ mA})(2\text{ k}\Omega) = -8\text{ V}$$

$$\mathbf{A}_v = \frac{\mathbf{E}_o}{\mathbf{E}_i} = -160$$

$$\mathbf{E}_i = \frac{\mathbf{E}_o}{-160} = \frac{-8\text{ V}}{-160\text{ V}} = \mathbf{50\text{ mV}}$$

c. $$I_i = \frac{E_g - E_i}{R_g} = \frac{70\text{ mV} - 50\text{ mV}}{0.4\text{ k}\Omega} = 50\ \mu\text{A}$$

$$Z_i = \frac{E_i}{I_i} = \frac{50\text{ mV}}{50\ \mu\text{A}} = \mathbf{1\text{ k}\Omega}$$

13. a. $$\mathbf{A}_G = \mathbf{A}_v^2 \frac{R_i}{R_L}$$

$$= (-392.98)^2 \frac{2.2\text{ k}\Omega}{5.6\text{ k}\Omega}$$

$$= \mathbf{6.067 \times 10^4}$$

$$\mathbf{A}_v = \mathbf{A}_{v_{NL}} \frac{R_L}{R_L + R_o}$$

$$= (-3200)\left[\frac{5.6\text{ k}\Omega}{5.6\text{ k}\Omega + 40\text{ k}\Omega}\right]$$

$$= -392.98$$

$$\mathbf{A_G} = -\mathbf{A}_v\mathbf{A}_i$$

$$= -(-392.98)(154.39)$$

$$= \mathbf{6.067 \times 10^4}$$

$$\mathbf{A}_i = -\mathbf{A}_{v_{NL}} \frac{R_i}{R_L + R_o}$$

$$= -(-3200)\left[\frac{2.2\text{ k}\Omega}{5.6\text{ k}\Omega + 40\text{ k}\Omega}\right]$$

$$= 154.39$$

b. $$\mathbf{A}_{v_T} = \mathbf{A}_v \frac{\mathbf{Z}_i}{\mathbf{Z}_i + R_g} = (-392.98)\left[\frac{2.2\text{ k}\Omega}{2.2\text{ k}\Omega + 0.5\text{ k}\Omega}\right] = \mathbf{-320.21}$$

$$\mathbf{A}_{i_T} = -\mathbf{A}_{v_T} \frac{R_g + \mathbf{Z}_i}{R_L} = -(-320.21)\left[\frac{0.5\text{ k}\Omega + 2.2\text{ k}\Omega}{5.6\text{ k}\Omega}\right] = \mathbf{154.39}$$

$$\mathbf{A}_{G_T} = \mathbf{A}_{v_T}^2\left[\frac{R_g + R_i}{R_L}\right] = (-320.21)^2\left[\frac{0.5\text{ k}\Omega + 2.2\text{ k}\Omega}{5.6\text{ k}\Omega}\right] = \mathbf{4.94 \times 10^4}$$

$$\mathbf{A}_{G_T} = -\mathbf{A}_{v_T}\mathbf{A}_{i_T} = -(-320.21)(154.39) = \mathbf{4.94 \times 10^4}$$

15. a. $$\mathbf{A}_{v_T} = \mathbf{A}_{v_1} \cdot \mathbf{A}_{v_2} = (-30)(-50) = \mathbf{1500}$$

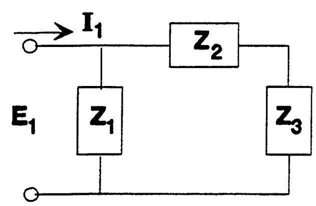
b. $$\mathbf{A}_{i_T} = \mathbf{A}_{v_T} \frac{\mathbf{Z}_{i_1}}{R_L} = (1500)\left[\frac{1\text{ k}\Omega}{8\text{ k}\Omega}\right] = \mathbf{187.5}$$

c. $$\mathbf{A}_{i_1} = -\mathbf{A}_{v_1} \frac{\mathbf{Z}_{i_1}}{R_{L_1}} = -(-30)\left[\frac{1\text{ k}\Omega}{2\text{ k}\Omega}\right] = \mathbf{15}$$

$$A_{i_2} = -A_{v_2}\frac{Z_{i_2}}{R_{L_2}} = -(-50)\left[\frac{2\text{ k}\Omega}{8\text{ k}\Omega}\right] = \mathbf{12.5}$$

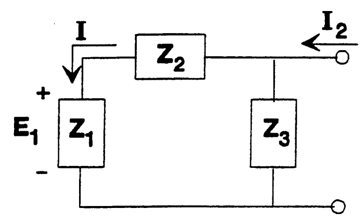
d. $A_{i_T} = A_{i_1} \cdot A_{i_2} = (15)(12.5) = \mathbf{187.5}$ as above

17. a.



$$z_{11} = \left.\frac{E_1}{I_1}\right|_{I_2=0} = Z_1 \| (Z_2 + Z_3)$$

$$z_{11} = \frac{Z_1Z_2 + Z_1Z_3}{Z_1 + Z_2 + Z_3}$$



$$I = \frac{Z_3I_2}{Z_1 + Z_2 + Z_3}$$

$$E_1 = I_1Z_1 = \frac{(Z_3I_2)(Z_1)}{Z_1 + Z_2 + Z_3}$$

$$z_{12} = \left.\frac{E_1}{I_2}\right|_{I_1=0} = \frac{Z_1Z_3}{Z_1 + Z_2 + Z_3}$$

$$z_{21} = \left.\frac{E_2}{I_1}\right|_{I_2=0}$$ Mirror image of z_{12}

$$\therefore z_{21} = \frac{Z_1Z_3}{Z_1 + Z_2 + Z_3}$$

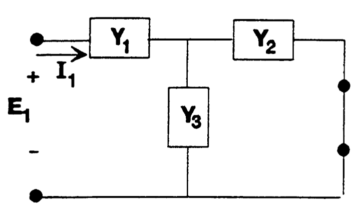
$$z_{22} = \left.\frac{E_2}{I_2}\right|_{I_1=0}$$ Mirror image of z_{11}

$$\therefore z_{22} = Z_3 \| (Z_1 + Z_2)$$

$$= \frac{Z_1Z_3 + Z_2Z_3}{Z_1 + Z_2 + Z_3}$$

b. —

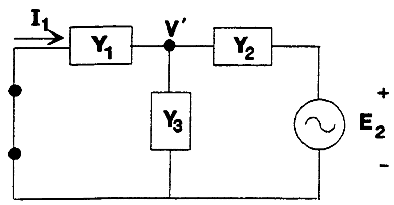
19. a.



$$y_{11} = \left.\frac{I_1}{E_1}\right|_{E_2=0} \quad Y_T = Y_1 \| (Y_2 + Y_3)$$

$$= \frac{Y_1(Y_2 + Y_3)}{Y_1 + Y_2 + Y_3}$$

$$= \frac{Y_1Y_2 + Y_1Y_3}{Y_1 + Y_2 + Y_3}$$



Nodal analysis:

$$V'[Y_1 + Y_2 + Y_3] = E_2Y_2$$
$$V' = I_1/Y_1$$

and

$$\frac{-I_1}{Y_1}[Y_1 + Y_2 + Y_3] = E_2Y_2$$

$$y_{12} = \left.\frac{I_1}{E_2}\right|_{E_1=0} = \frac{-Y_1Y_2}{Y_1 + Y_2 + Y_3}$$

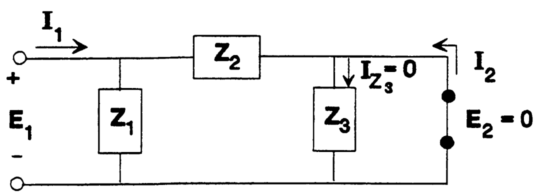
$$y_{21} = \left.\frac{I_2}{E_1}\right|_{E_2=0}$$ Mirror image of y_{12}

$$\therefore\ y_{21} = \frac{-Y_1Y_2}{Y_1 + Y_2 + Y_3}$$

$$y_{22} = \left.\frac{I_2}{E_2}\right|_{E_1=0}$$ Mirror image of y_{11}

$$y_{22} = Y_T = Y_2 \,\|\, (Y_1 + Y_3)$$
$$= \frac{Y_1Y_2 + Y_2Y_3}{Y_1 + Y_2 + Y_3}$$

21.

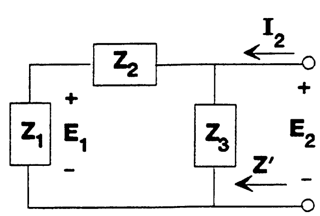


$$h_{11} = \left.\frac{E_1}{I_1}\right|_{E_2=0} = Z_T = Z_1 \,\|\, Z_2 = \frac{Z_1Z_2}{Z_1 + Z_2}$$

Using the above figure:

$$\text{CDR:}\quad I_2 = \frac{-Z_1(I_1)}{Z_1 + Z_2}$$

$$h_{21} = \left.\frac{I_2}{I_1}\right|_{E_2=0} = \frac{-Z_1}{Z_1 + Z_2}$$



$$h_{12} = \left.\frac{E_1}{E_2}\right|_{I_1=0}$$

$$\text{VDR:}\qquad E_1 = \frac{Z_1E_2}{Z_1 + Z_2}$$

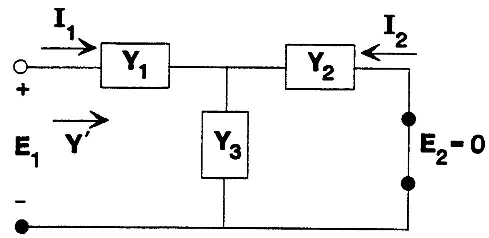
$$h_{12} = \left.\frac{E_1}{E_2}\right|_{I_1=0} = \frac{Z_1}{Z_1 + Z_2}$$

Using above figure:

$$h_{22} = \left.\frac{I_2}{E_2}\right|_{I_1=0} \quad : Z' = Z_3 \| (Z_1 + Z_2) = \frac{Z_1Z_3 + Z_2Z_3}{Z_1 + Z_2 + Z_3}$$

$$h_{22} = \frac{1}{Z'} = \frac{Z_1 + Z_2 + Z_3}{Z_1Z_3 + Z_2Z_3}$$

23. $h_{11} = \left.\frac{E_1}{I_1}\right|_{E_2=0}$



$$Y' = Y_1 \| (Y_2 + Y_3)$$

$$Y' = \frac{Y_1Y_2 + Y_1Y_3}{Y_1 + Y_2 + Y_3}$$

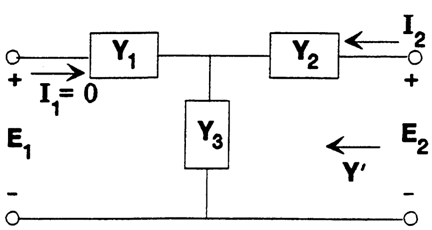
$$h_{11} = \frac{1}{Y'} = \frac{Y_1 + Y_2 + Y_3}{Y_1Y_2 + Y_1Y_3}$$

$$h_{21} = \left.\frac{I_2}{I_1}\right|_{E_2=0}$$

From above figure:

CDR: $\quad I_2 = \dfrac{-Z_3I_1}{Z_3 + Z_2} = \dfrac{-I_1/Y_3}{1/Y_3 + 1/Y_2}$

and $\quad h_{21} = \left.\dfrac{I_2}{I_1}\right|_{E_2=0} = \dfrac{-1/Y_3}{1/Y_3 + 1/Y_2} = \dfrac{-Y_2}{Y_2 + Y_3}$



$$h_{12} = \left.\frac{E_1}{E_2}\right|_{I_1=0}$$

VDR: $E_1 = \dfrac{Z_3E_2}{Z_3 + Z_2} = \dfrac{-1/Y_3E_2}{1/Y_3 + 1/Y_2}$

and $E_1 = \dfrac{Y_2E_2}{Y_2 + Y_3}$

with $h_{12} = \left.\dfrac{E_1}{E_2}\right|_{I_1=0} = \dfrac{Y_2}{Y_2 + Y_3}$

$h_{22} = \left.\dfrac{I_2}{E_2}\right|_{I_1=0} \quad Y' = \dfrac{Y_2 \cdot Y_3}{Y_2 + Y_3}$ (from above figure)

$$h_{22} = \left.\frac{I_2}{E_2}\right|_{I_1=0} = Y' = \frac{Y_2Y_3}{Y_2 + Y_3}$$

25. a. Eq. 26.45:

$$A_i = \frac{h_f}{1 + h_o Z_L} = \frac{50}{1 + \left[\dfrac{1}{40\ \text{k}\Omega}\right](2\ \text{k}\Omega)} = \mathbf{47.62}$$

b. Eq. 26.46:

$$\mathbf{A}_v = \frac{-h_f \mathbf{Z}_L}{h_i(1 + h_o \mathbf{Z}_L) - h_r h_f \mathbf{Z}_L}$$

$$= \frac{-50(2\ \text{k}\Omega)}{1\ \text{k}\Omega(1 + 0.05) - (4 \times 10^{-4})(50)(2\ \text{k}\Omega)} = \mathbf{-99}$$

27. $\mathbf{z}_{11} = 1\ \text{k}\Omega \angle 0°$, $\mathbf{z}_{12} = 5\ \text{k}\Omega \angle 90°$, $\mathbf{z}_{21} = 10\ \text{k}\Omega \angle 0°$, $\mathbf{z}_{22} = 2\ \text{k}\Omega - j4\ \text{k}\Omega$, $\mathbf{Z}_L = 1\ \text{k}\Omega \angle 0°$

$$\mathbf{Z}_i = \frac{\mathbf{E}}{\mathbf{I}} = \mathbf{z}_{11} - \frac{\mathbf{z}_{12}\mathbf{z}_{21}}{\mathbf{z}_{22} + \mathbf{Z}_L} = 1\ \text{k}\Omega - \frac{(5\ \text{k}\Omega \angle 90°)(10\ \text{k}\Omega)}{2\ \text{k}\Omega - j4\ \text{k}\Omega + 1\ \text{k}\Omega} = \mathbf{9{,}219.5\ \Omega \angle -139.40°}$$

$$\mathbf{Z}_o = \frac{\mathbf{E}_2}{\mathbf{I}_2} = \mathbf{z}_{22} - \frac{\mathbf{z}_{12}\mathbf{z}_{21}}{R_s + \mathbf{z}_{11}} = 2\ \text{k}\Omega - j4\ \text{k}\Omega - \frac{(5\ \text{k}\Omega \angle 90°)(10\ \text{k}\Omega)}{1\ \text{k}\Omega + 1\ \text{k}\Omega} = \mathbf{29.07\ k\Omega \angle -86.05°}$$

29. $$\mathbf{h}_{11} = \frac{\mathbf{z}_{11}\mathbf{z}_{22} - \mathbf{z}_{12}\mathbf{z}_{21}}{\mathbf{z}_{22}} = \frac{(4\ \text{k}\Omega)(4\ \text{k}\Omega) - (2\ \text{k}\Omega)(3\ \text{k}\Omega)}{4\ \text{k}\Omega} = \mathbf{2.5\ k\Omega}$$

$$\mathbf{h}_{12} = \frac{\mathbf{z}_{12}}{\mathbf{z}_{22}} = \frac{2\ \text{k}\Omega}{4\ \text{k}\Omega} = \mathbf{0.5}$$

$$\mathbf{h}_{21} = -\frac{\mathbf{z}_{21}}{\mathbf{z}_{22}} = -\frac{3\ \text{k}\Omega}{4\ \text{k}\Omega} = \mathbf{-0.75}$$

$$\mathbf{h}_{22} = \frac{1}{\mathbf{z}_{22}} = \frac{1}{4\ \text{k}\Omega} = \mathbf{0.25\ mS}$$

CHAPTER 26 (Even)

2. $\mathbf{Z}_i = \dfrac{\mathbf{E}_i}{\mathbf{I}_i} = \dfrac{120 \text{ V } \angle 0°}{6.2 \text{ A } \angle -10.8°} = 19.35 \ \Omega \angle 10.8° = 19 \ \Omega + j3.623 \ \Omega$

$f = 60$ Hz: $R = \mathbf{19 \ \Omega}$, $L = \dfrac{X_L}{2\pi f} = \dfrac{3.623 \ \Omega}{2\pi(60 \text{ Hz})} = \mathbf{9.61 \text{ mH}}$

4. $I_o = \dfrac{E_g - E_o}{R_s} = \dfrac{4 \text{ V} - 3.8 \text{ V}}{2 \text{ k}\Omega} = \dfrac{0.2 \text{ V}}{2 \text{ k}\Omega} = 0.1 \text{ mA}(p - p)$

$Z_o = \dfrac{E_o}{I_o} = \dfrac{3.8 \text{ V}(p - p)}{0.1 \text{ mA}(p - p)} = \mathbf{38 \text{ k}\Omega}$

6. $E_{o_{(\text{peak})}} = \sqrt{2} \ 0.6 \text{ V}_{(\text{rms})} = 0.849 \text{ V}$

$E_{o_{(p-p)}} = 2\left(E_{o_{(\text{peak})}}\right) = 2(0.849 \text{ V}) = 1.697 \text{ V}$

$I_o = \dfrac{E_g - E_o}{R_s} = \dfrac{1.8 \text{ V} - 1.697 \text{ V}}{2 \text{ k}\Omega} = 51.5 \ \mu\text{A}(p - p)$

$Z_o = \dfrac{E_o}{I_o} = \dfrac{1.697 \text{ V}(p - p)}{51.5 \ \mu\text{A}(p - p)} = \mathbf{32.95 \text{ k}\Omega}$

8. $\mathbf{E}_i = \mathbf{I}_i\mathbf{Z}_i = (10 \ \mu\text{A} \angle 0°)(1.8 \text{ k}\Omega \angle 0°) = 18 \text{ mV} \angle 0°$

$E_{i_{(\text{peak})}} = \sqrt{2} \ (18 \text{ mV}) = 25.46 \text{ mV}$

$E_{i_{(p-p)}} = 2(25.46 \text{ mV}) = 50.92 \text{ mV}$

$\mathbf{A}_{v_{\text{NL}}} = \dfrac{\mathbf{E}_o}{\mathbf{E}_i} = \dfrac{4.05 \text{ V} \angle 180°}{50.92 \text{ mV} \angle 0°} = 79.54 \angle 180° = -79.54$

10. $\mathbf{A}_{v_{\text{NL}}} = \dfrac{-1400 \text{ mV}}{1.2 \text{ mV} \angle 0°} = -1200$

$\mathbf{A}_v = \dfrac{-192 \text{ mV}}{1.2 \text{ mV}} = -160$

$R_o = R_L \left[\dfrac{\mathbf{A}_{v_{\text{NL}}}}{\mathbf{A}_v} - 1\right]$

$= 4.7 \text{ k}\Omega \left[\dfrac{-1200}{-160} - 1\right]$

$= \mathbf{30.55 \text{ k}\Omega}$

12. a. $\mathbf{A}_i = -\mathbf{A}_{v_{\text{NL}}} \dfrac{R_i}{R_L + R_o}$

$= \dfrac{-(-3200)(2.2 \text{ k}\Omega)}{5.6 \text{ k}\Omega + 40 \text{ k}\Omega}$

$= \mathbf{154.39}$

b. $$\mathbf{A}_{i_T} = -\mathbf{A}_{v_T}\left[\frac{R_g + Z_i}{R_L}\right]$$
$$= -\left[\frac{\mathbf{A}_v Z_i}{Z_i + R_g}\right]\left[\frac{R_g + Z_i}{R_L}\right]$$
$$\mathbf{A}_{i_T} = -\mathbf{A}_v\frac{Z_i}{R_L} = -\left[\mathbf{A}_{v_{\mathrm{NL}}}\frac{R_L}{R_L + R_o}\right]\frac{Z_i}{R_L}$$
$$= -\mathbf{A}_{v_{\mathrm{NL}}}\frac{Z_i}{R_L + R_o}$$
$$= \frac{-(-3200)(2.2\ \mathrm{k}\Omega)}{5.6\ \mathrm{k}\Omega + 40\ \mathrm{k}\Omega}$$
$$= \mathbf{154.39}$$

c. Same result since $\mathbf{I}_i = \mathbf{I}_g$

14. a. $$\mathbf{A}_i = \frac{\mathbf{I}_o}{\mathbf{I}_i} = -\mathbf{A}_v\frac{Z_i}{R_L}$$
$$= \frac{-(-160)(0.75\ \mathrm{k}\Omega)}{2\ \mathrm{k}\Omega}$$
$$= \mathbf{60}$$

b. $$A_{G_T} = \frac{P_L}{P_g} = A_{v_T}^2\left[\frac{R_g + R_i}{R_L}\right]$$
$$\mathbf{A}_{v_T} = \mathbf{A}_v\frac{Z_i}{Z_i + R_g}$$
$$= \frac{(-160)(0.75\ \mathrm{k}\Omega)}{0.75\ \mathrm{k}\Omega + 0.4\ \mathrm{k}\Omega} = -104.35$$
$$A_{G_T} = (104.35)^2\left[\frac{0.4\ \mathrm{k}\Omega + 0.75\ \mathrm{k}\Omega}{2\ \mathrm{k}\Omega}\right]$$
$$= \mathbf{6.261 \times 10^3}$$

16. a. $$\mathbf{A}_{v_T} = \mathbf{A}_{v_1} \cdot \mathbf{A}_{v_2} \cdot \mathbf{A}_{v_3}$$
$$-6912 = (-12)(A_{v_2})(-32)$$
$$\mathbf{A}_{v_2} = \mathbf{-18}$$

b. $$\mathbf{A}_{i_1} = \frac{-\mathbf{A}_{v_1}Z_{i_1}}{R_{L_1}} = \frac{-\mathbf{A}_{v_1}Z_{i_1}}{Z_{i_2}}$$
$$4 = \frac{-(-12)(1\ \mathrm{k}\Omega)}{Z_{i_2}}$$
$$Z_{i_2} = \mathbf{3\ k\Omega}$$

c. $\mathbf{A}_{i_3} = \dfrac{-\mathbf{A}_{v_3} Z_{i_3}}{R_{L_3}} = \dfrac{-(-32)(2\text{ k}\Omega)}{2.2\text{ k}\Omega}$

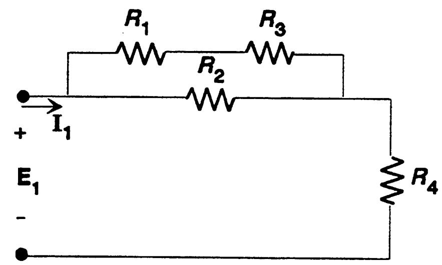
$= \mathbf{29.09}$

$\mathbf{A}_{i_T} = \mathbf{A}_{i_1} \cdot \mathbf{A}_{i_2} \cdot \mathbf{A}_{i_3}$

$= (4)(26)(29.09)$

$= \mathbf{3.025 \times 10^3}$

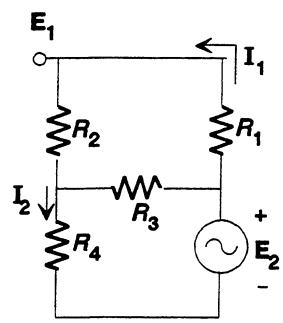
18. a. $\mathbf{z}_{11} = \left.\dfrac{\mathbf{E}_1}{\mathbf{I}_1}\right|_{\mathbf{I}_2=0}$



$\mathbf{z}_{11} = R_4 + R_2 \| (R_1 + R_3)$

$= R_4 + \dfrac{R_2(R_1 + R_3)}{R_1 + R_2 + R_3}$

$\mathbf{z}_{12} = \left.\dfrac{\mathbf{E}_1}{\mathbf{I}_2}\right|_{\mathbf{I}_1=0}$

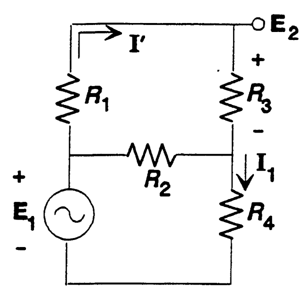


$\mathbf{I}' = \dfrac{R_2(\mathbf{I}_2)}{(R_1 + R_2) + R_3}$

$\mathbf{E}_1 = \mathbf{I}'R_2 + \mathbf{I}_2 R_4$

$= \dfrac{R_2 R_3 \mathbf{I}_2}{R_1 + R_2 + R_3} + R_4 \mathbf{I}_2$

and $\mathbf{z}_{12} = \dfrac{\mathbf{E}_1}{\mathbf{I}_2} = \dfrac{R_2 R_3}{R_1 + R_2 + R_3} + R_4 = \dfrac{R_2 R_3 + R_4(R_1 + R_2 + R_3)}{R_1 + R_2 + R_3}$



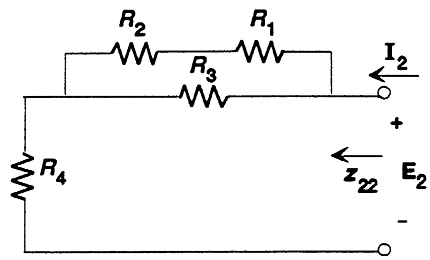
$\mathbf{E}_2 = \mathbf{I}'R_3 + \mathbf{I}_1 R_4$

CDR: $\mathbf{I}' = \dfrac{R_2(\mathbf{I}_1)}{(R_1 + R_3) + R_2}$

$\mathbf{E}_2 = \dfrac{R_2 R_3 \mathbf{I}_1}{R_1 + R_2 + R_3} + \mathbf{I}_1 R_4$

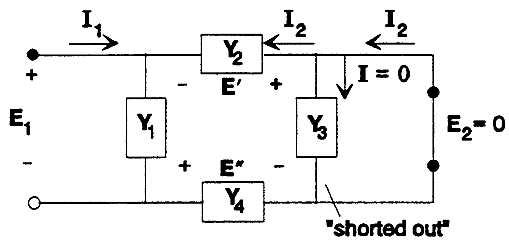
and $\mathbf{z}_{21} = \dfrac{\mathbf{E}_2}{\mathbf{I}_1} = \dfrac{R_2 R_3}{R_1 + R_2 + R_3} + R_4 = \dfrac{R_2 R_3 + R_4(R_1 + R_2 + R_3)}{R_1 + R_2 + R_3}$

$$z_{22} = \left.\frac{E_2}{I_2}\right|_{I_1=0}$$



$$z_{22} = R_4 + R_3 \| (R_1 + R_2)$$
$$= R_4 + \frac{R_3(R_1 + R_2)}{R_3 + (R_1 + R_2)}$$

20. a. $$y_{11} = \left.\frac{I_1}{E_1}\right|_{E_2=0}$$

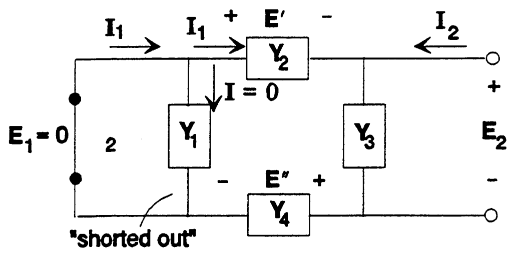


$$y_{11} = Y_1 + Y_2 \| Y_4$$
$$= Y_1 + \frac{Y_2Y_4}{Y_2 + Y_4}$$
$$= \frac{Y_1(Y_2 + Y_4) + Y_2Y_4}{Y_2 + Y_4}$$

$$y_{21} = \left.\frac{I_2}{E_1}\right|_{E_2=0} \quad \text{(using the above diagram)}$$

$$E_1 = \frac{I_2}{Y_1} = -(E' + E'') = -\left[\frac{I_2}{Y_2} + \frac{I_2}{Y_4}\right] = -I_2\left[\frac{1}{Y_2} + \frac{1}{Y_4}\right]$$

and $E_1 = -I_2\left[\frac{Y_4 + Y_2}{Y_4Y_2}\right]$ with $y_{21} = \frac{I_2}{E_1} = -\frac{Y_2Y_4}{Y_2 + Y_4}$



$$y_{12} = \left.\frac{I_1}{E_2}\right|_{E_1=0}$$

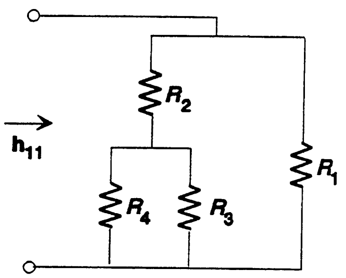
$$E_2 = \frac{I_1}{Y_3} = -(E' + E'') = -\left[\frac{I_1}{Y_2} + \frac{I_1}{Y_4}\right] = -I_1\left[\frac{1}{Y_2} + \frac{1}{Y_4}\right]$$

and $y_{12} = -\frac{Y_2Y_4}{Y_2 + Y_4} = y_{21}$

$$y_{22} = \left.\frac{\mathbf{I}_2}{\mathbf{E}_2}\right|_{\mathbf{E}_1=0} \qquad y_{22} = \mathbf{Y}_3 + \mathbf{Y}_2 \| \mathbf{Y}_4 = \mathbf{Y}_3 + \frac{\mathbf{Y}_2\mathbf{Y}_4}{\mathbf{Y}_2 + \mathbf{Y}_4}$$

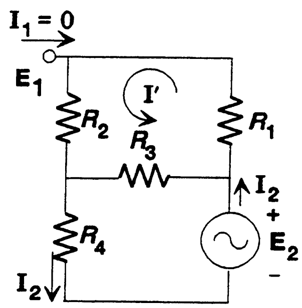
$$= \frac{\mathbf{Y}_3(\mathbf{Y}_2 + \mathbf{Y}_4)\mathbf{Y}_2\mathbf{Y}_4}{\mathbf{Y}_2 + \mathbf{Y}_4}$$

22. a.



$$\mathbf{h}_{11} = \left.\frac{\mathbf{E}_1}{\mathbf{I}_1}\right|_{\mathbf{E}_2=0}$$

$$= \mathbf{Z}_i = \mathbf{R}_1 \| (\mathbf{R}_2 + \mathbf{R}_3 \| \mathbf{R}_4)$$



$$\mathbf{h}_{12} = \left.\frac{\mathbf{E}_1}{\mathbf{E}_2}\right|_{\mathbf{I}_1=0}$$

$$\mathbf{E}_1 = \mathbf{I}'R_2 + \mathbf{I}_2R_4$$

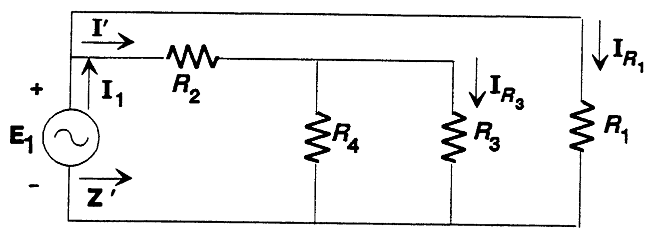
$$\mathbf{I}' = \frac{R_3(\mathbf{I}_2)}{R_1 + R_2 + R_3}$$

$$\therefore \mathbf{E}_1 = \frac{R_2R_3\mathbf{I}_2}{R_1 + R_2 + R_3} + \mathbf{I}_2R_4$$

$$\text{and } \mathbf{I}_2 = \frac{\mathbf{E}_2}{\mathbf{Z}'} = \frac{\mathbf{E}_2}{R_4 + R_3 \| (R_1 + R_2)}$$

$$\mathbf{E}_1 = \left[\frac{R_2R_3}{R_1 + R_2 + R_3} + R_4\right]\left[\frac{\mathbf{E}_2}{R_4 + \dfrac{R_3R_1 + R_2R_3}{R_1 + R_2 + R_3}}\right]$$

$$\text{and } \mathbf{h}_{12} = \frac{\mathbf{E}_1}{\mathbf{E}_2} = \frac{R_2R_3 + R_4(R_1 + R_2 + R_3)}{R_1R_3 + R_2R_3 + R_4(R_1 + R_2 + R_3)}$$



$$\mathbf{Z}' = R_2 + R_3 \| R_4$$

$$\mathbf{I}_{R_1} = \frac{(\mathbf{Z}')(\mathbf{I}_1)}{\mathbf{Z}' + R_1}$$

$$\mathbf{I}' = \frac{R_1\mathbf{I}_1}{R_1 + \mathbf{Z}'}$$

$$\mathbf{I}_{R_3} = \frac{R_4\mathbf{I}'}{R_4 + R_3} = \frac{R_4}{R_4 + R_3}\left[\frac{R_1(\mathbf{I}_1)}{R_1 + \mathbf{Z}'}\right]$$

$$= \frac{R_1R_4\mathbf{I}_1}{(R_3 + R_4)(R_1 + \mathbf{Z}')}$$

$$\mathbf{I}_2 = -\mathbf{I}_{R_1} - \mathbf{I}_{R_3} = \frac{-\mathbf{Z}'\mathbf{I}_1}{\mathbf{Z}' + R_1} - \frac{R_1R_4\mathbf{I}_1}{(R_3 + R_4)(R_1 + \mathbf{Z}')}$$

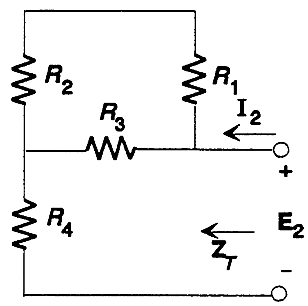
$$\mathbf{h}_{12} = \left.\frac{\mathbf{I}_2}{\mathbf{I}_1}\right|_{\mathbf{E}_2=0} = -\left[\frac{\mathbf{Z}'}{\mathbf{Z}' + R_1} + \frac{R_1R_4}{(R_3 + R_4)(R_1 + \mathbf{Z}')}\right]$$

$$= -\frac{1}{R_1 + \mathbf{Z}'}\left[\mathbf{Z}' + \frac{R_1R_4}{R_3 + R_4}\right]$$

$$\mathbf{h}_{22} = \left.\frac{\mathbf{I}_2}{\mathbf{E}_2}\right|_{\mathbf{I}_1=0} = \frac{1}{\mathbf{Z}_T}$$

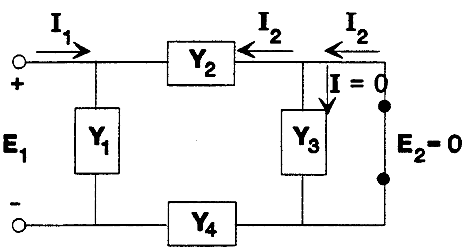
$$\mathbf{Z}_T = R_4 + R_3 \| (R_1 + R_2)$$

$$\mathbf{h}_{22} = \frac{1}{R_4 + R_3 \| (R_1 + R_2)}$$



A Y-Δ conversion would have simplified the problem to one similar to Fig. 26.70.

24.

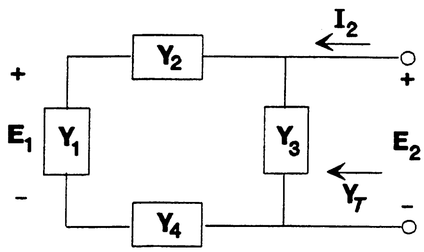


$$\mathbf{h}_{11} = \left.\frac{\mathbf{E}_1}{\mathbf{I}_1}\right|_{\mathbf{E}_2=0} = \frac{1}{\mathbf{Y}_T} = \frac{1}{\mathbf{Y}_1 + \mathbf{Y}_2 \| \mathbf{Y}_4}$$

$$\mathbf{h}_{21} = \left.\frac{\mathbf{I}_2}{\mathbf{I}_1}\right|_{\mathbf{E}_2=0} : \text{CDR} \rightarrow \mathbf{I}_2 = \frac{-\mathbf{Z}_1(\mathbf{I}_1)}{\mathbf{Z}_1 + \mathbf{Z}_2 + \mathbf{Z}_4} = \frac{-1/\mathbf{Y}_1(\mathbf{I}_1)}{1/\mathbf{Y}_1 + 1/\mathbf{Y}_2 + 1/\mathbf{Y}_4}$$

$$= \frac{-1/\mathbf{Y}_1(\mathbf{I}_1)}{\dfrac{\mathbf{Y}_2\mathbf{Y}_4 + \mathbf{Y}_1\mathbf{Y}_4 + \mathbf{Y}_1\mathbf{Y}_2}{\mathbf{Y}_1\mathbf{Y}_2\mathbf{Y}_4}}$$

$$\text{and } \mathbf{h}_{21} = -\frac{\mathbf{Y}_2\mathbf{Y}_4}{\mathbf{Y}_2\mathbf{Y}_4 + \mathbf{Y}_1\mathbf{Y}_4 + \mathbf{Y}_1\mathbf{Y}_2}$$



$$h_{12} = \left.\frac{E_1}{E_2}\right|_{I_1=0}$$

$$\text{VDR: } E_1 = \frac{Z_1(E_2)}{Z_1 + Z_2 + Z_4} = \frac{1/Y_1\ (E_2)}{1/Y_1 + 1/Y_2 + 1/Y_4}$$

$$\text{and } h_{12} = \frac{Y_2Y_4}{Y_2Y_4 + Y_1Y_4 + Y_1Y_2}$$

$$h_{22} = \left.\frac{I_2}{E_2}\right|_{I_1=0} = Y_T \text{ (using the above figure)}$$

$$Y_T = Y_3 + Y_1 \| Y_2 \| Y_4$$

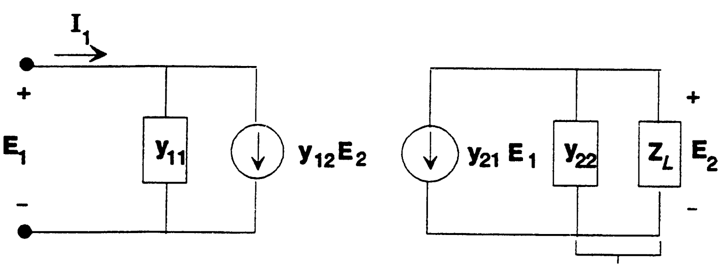
$$= Y_3 + \frac{Y_1Y_2Y_4}{Y_1Y_2 + Y_1Y_4 + Y_2Y_4}$$

26. a. $$Z_i = \frac{E_1}{I_1} = h_i - \frac{h_r h_f Z_L}{1 + h_o Z_L}$$

$$= 1\text{ k}\Omega - \frac{(4 \times 10^{-4})(50)(2\text{ k}\Omega)}{1 + \left[\frac{1}{40\text{ k}\Omega}\right](2\text{ k}\Omega)} = \mathbf{961.9\ \Omega}$$

b. $$Z_o = \frac{1}{h_o - \frac{h_r h_f}{h_i + R_s}} = \frac{1}{\frac{1}{40\text{ k}\Omega} - \frac{(4 \times 10^{-4})(50)}{1\text{ k}\Omega + 0}} = \mathbf{200\ k\Omega}$$

28.



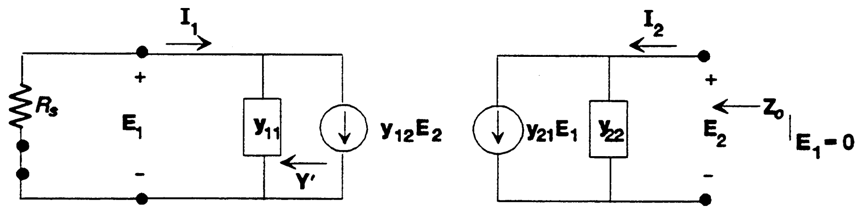
$$1/y_{22} \| Z_L = \frac{1/y_{22}Z_L}{1/y_{22} + Z_L} = \frac{Z_L}{1 + y_{22}Z_L}$$

$$E_2 = -y_{21}E_1\left[\frac{Z_L}{1 + y_{22}Z_L}\right]$$

$$I_1 = E_1y_{11} + y_{12}E_2 = E_1y_{11} + y_{12}\left[-y_{21}E_1\left(\frac{Z_L}{1 + y_{22}Z_L}\right)\right]$$

$$\frac{\mathbf{I}_1}{\mathbf{E}_1} = \mathbf{y}_{11} - \frac{\mathbf{y}_{12}\mathbf{y}_{21}\mathbf{Z}_L}{1 + \mathbf{y}_{22}\mathbf{Z}_L}$$

and $$\mathbf{Z}_i = \frac{\mathbf{E}_1}{\mathbf{I}_1} = \frac{1}{\mathbf{y}_{11} - \dfrac{\mathbf{y}_{12}\mathbf{y}_{21}\mathbf{Z}_L}{1 + \mathbf{y}_{22}\mathbf{Z}_L}}$$



$$\mathbf{Y}' = \mathbf{y}_{11} + \frac{1}{R_s}$$

$$\mathbf{E}_1 = \frac{-\mathbf{y}_{12}\mathbf{E}_2}{\mathbf{Y}'} = \frac{-\mathbf{y}_{12}\mathbf{E}_2}{\mathbf{y}_{11} + \dfrac{1}{R_s}} = \frac{-\mathbf{y}_{12}R_s\mathbf{E}_2}{\mathbf{y}_{11}R_s + 1}$$

$$\mathbf{I}_2 = \mathbf{y}_{21}\mathbf{E}_1 + \mathbf{y}_{22}\mathbf{E}_2 = \mathbf{y}_{21}\left[\frac{-\mathbf{y}_{12}R_s\mathbf{E}_2}{\mathbf{y}_{11}R_s + 1}\right] + \mathbf{y}_{22}\mathbf{E}_2$$

$$\frac{\mathbf{I}_2}{\mathbf{E}_2} = -\frac{\mathbf{y}_{12}\mathbf{y}_{21}R_s}{\mathbf{y}_{11}R_s + 1} + \mathbf{y}_{22}$$

and $$\mathbf{Z}_o = \left.\frac{\mathbf{E}_2}{\mathbf{I}_2}\right|_{\mathbf{E}_1=0} = \frac{1}{\mathbf{y}_{22} - \dfrac{\mathbf{y}_{12}\mathbf{y}_{21}R_s}{1 + \mathbf{y}_{11}R_s}}$$

30. a. $$\Delta_{\mathbf{h}} = \mathbf{h}_{11}\mathbf{h}_{22} - \mathbf{h}_{12}\mathbf{h}_{21} = (10^3)(20 \times 10^{-6}) - (2 \times 10^{-4})(100)$$
$$= 20 \times 10^{-3} - 20 \times 10^{-3} = 0$$

$$\mathbf{z}_{11} = \frac{\Delta_{\mathbf{h}}}{\mathbf{Z}_{22}} = \mathbf{0\ \Omega}, \ \mathbf{z}_{12} = \frac{\mathbf{h}_{12}}{\mathbf{h}_{22}} = \frac{2 \times 10^{-4}}{20 \times 10^{-6}\ \mathrm{S}} = \mathbf{10\ \Omega}$$

$$\mathbf{z}_{21} = \frac{-\mathbf{h}_{21}}{\mathbf{h}_{22}} = \frac{-100}{20 \times 10^{-6}\ \mathrm{S}} = \mathbf{-5\ M\Omega}, \ \mathbf{z}_{22} = \frac{1}{\mathbf{h}_{22}} = \mathbf{50\ k\Omega}$$

b. $$\mathbf{y}_{11} = \frac{1}{\mathbf{h}_{11}} = \frac{1}{10^3\ \Omega} = \mathbf{10^{-3}\ S}, \ \mathbf{y}_{12} = \frac{-\mathbf{h}_{12}}{\mathbf{h}_{11}} = \frac{-2 \times 10^{-4}}{10^3\ \Omega} = \mathbf{-2 \times 10^{-7}\ S}$$

$$\mathbf{y}_{21} = \frac{\mathbf{h}_{21}}{\mathbf{h}_{11}} = \frac{100}{10^3\ \Omega} = \mathbf{100 \times 10^{-3}\ S}, \ \mathbf{y}_{22} = \frac{\Delta_{\mathbf{h}}}{\mathbf{h}_{11}} = \mathbf{0\ S}$$